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Agricultural Marketing Service

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# SHRINKAGE AND MOISTURE ABSORPTION OF GRAIN

## Abstracts and References

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Compiled by Corinne F. Kyle, under the direction
of E. G. Boerner, Research Specialist

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Washington, D. C.
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This material is issued in connection with the grain inspection work. It is for administrative use in replying to inquiries from correspondents concerning the changes in the moisture content of the grain while it is in storage and during transportation.

Contents

# SHRINKAGE AND MOISTURE ABSORPTION OF GRAIN

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## INTRODUCTION

For some years the U. S. Department of Agriculture and several of the State Agricultural Experiment Stations carried on experiments to test the shrinkage and moisture absorption of grain while in storage and during transit in cars.

Shrinkage or moisture absorption is influenced to a large extent by the weather conditions after harvesting in the fall, by the way in which the grain is handled on the farm, and by the manner of storing.

It is important for the farmer to know what effect the change in the moisture content has on the grade, on the shrinkage, and on the keeping qualities of grain in storage. The grain dealer is also interested, for he needs to know the conditions under which grain will change in grade, or will shrink or increase in weight when in storage or during transportation.

This summary publication gives in a very general way the results of some of the experiments that have been made to determine the shrinkage or moisture absorption of grain while in storage and during transit.

## SHRINKAGE OF SHELLED CORN

### Shelled Corn Stored in Hopper Scale of Elevator

Duvel, J. W. T., and Duval, Laurel. The shrinkage of corn in storage. U. S. Dept. Agr., Bur. Plant Indus. Circ. 81, 11pp. Washington, D. C., June 5, 1911.

The first of this series of experiments, by the Office of Grain Standardization Investigations, U. S. Department of Agriculture, on shrinkage was made on 500 bushels or 28,000 pounds of shelled corn stored in the hopper of a scale in an elevator, at Baltimore, for 147 days, or from January 5 to June 1, 1910. The corn was not handled

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1/ Part of the material included in this mimeograph was compiled by C. Louise Phillips Corbett while she was a member of the office staff.

except on May 14 when it was run out of the hopper and elevated three times and returned to the scale and held until June 1. When the corn was put in the hopper on January 5, the average moisture content was 18.8 percent, the average sound corn 97.1 percent, and the average germination 89.6 percent. The average temperature of the corn and of the air was 20° F. At the end of the experiment on June 1, the average moisture content was 14.7 percent, or 4.1 percent less than at the beginning of the experiment, sound corn 1.1 percent, and the germination 1 percent.

The corn remained in good condition until April 21, after which time it went "out of condition" became sour and hot, with a maximum temperature of 138° F. on May 2. On May 14 the corn was elevated three times and cooled to 55° F. From May 14 to June 1 the shrinkage was 2.6 percent.

The shrinkage records while the corn was in storage are as follows:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| From | January | 5 | to | February | 24 | ..... | 0.1 | of 1 percent |
| Do. | do. | 5 | do. | April | 8 | ..... | .2 | do. 1 do. |
| Do. | do. | 5 | do. | do. | 21 | ..... | .4 | do. 1 do. |
| Do. | April | 21 | do. | do. | 29 | ..... | .5 | do. 1 do. |
| Do. | do. | 29 | do. | May | 14 | ..... | 2.0 | percent (slightly more) |
| Do. | January | 3 | do. | do. | 14 | ..... | 3.0 | do. |
| During the three elevations on May 14 | | | | | | | 1.6 | do. |
| From May 14 to June 1 | | | | | | ..... | 2.6 | do. |
| From January 5 to June 1 | | | | | | ..... | 5.6 | do. or 1,522 pounds |

The 5.6 percent represents the natural shrinkage for the whole period of 147 days, calculated on the actual weight, after deducting the weight of the samples drawn for analysis, and exclusive of the loss during the three elevations. The total shrinkage including that during the three elevations was slightly more than 7 percent.

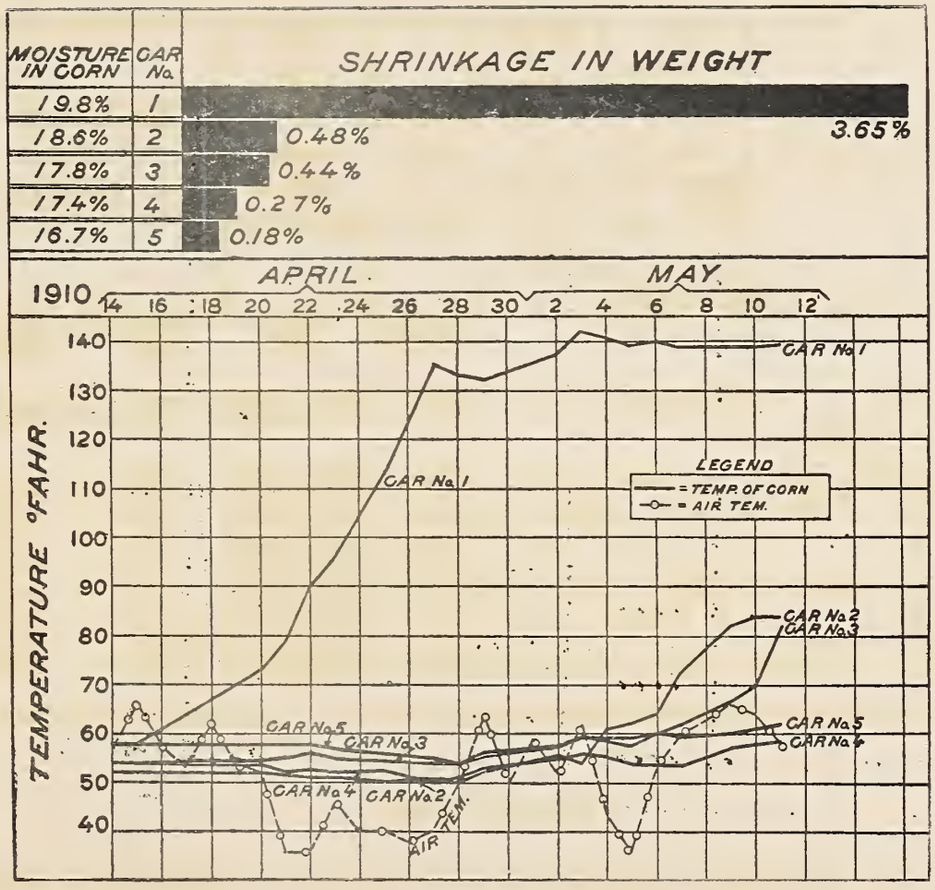
The corn became sour and hot after April 21, when the shrinkage began to increase, which shows that as long as the corn remained in good condition its rate of shrinkage was largely influenced by its moisture content, relative humidity, air temperature, and other weather conditions.

## Shelled Corn in Cars in Transit

The following table and chart were compiled from data secured by the U. S. Department of Agriculture.

Shrinkage in weight and temperature changes of each of five cars of corn in transit from Baltimore, Md. to Chicago, Ill. and return, from April 14 to May 11

| Car No. | Corn when loaded | | Shrinkage, or loss in weight | | Average temperature of corn when - | |
|---|---|---|---|---|---|---|
| | Moisture content | Net weight | | | Loaded | Unloaded |
| | Percent | Pounds | Pounds | Percent | °F. | °F. |
| 1 | 19.8 | 67,130 | 2,450 | 3.65 | 58 | 139½ |
| 2 | 18.6 | 67,120 | 320 | .48 | 52 | 84 |
| 3 | 17.8 | 65,920 | 290 | .44 | 54 | 82½ |
| 4 | 17.4 | 67,160 | 180 | .27 | 54 | 58½ |
| 5 | 16.7 | 66,940 | 120 | .18 | 58 | 62 |




The higher the moisture content of the corn the greater was its shrinkage in weight, and also the greater was its increase in temperature, during transit.

## Shelled Corn in Cars in Transit and in Storage on Track

Duvel, J.W.T., and Duval, Laurel. The shrinkage of shelled corn while in cars in transit. U.S. Dept. Agr. Bull. 48, 21pp. Washington,D.C.,Dec. 19,1913.

In January 1910, investigations were conducted by Grain Standarization Investigations, at Baltimore, Md., to determine the amount of natural shrinkage or loss in weight of shelled corn containing various percentages of moisture during transit in cars and while in storage in elevators.

The data on shrinkage contained in this bulletin comprise the results of four special shipments of corn from Baltimore, Md., to Chicago, Ill., and return. The first experiment made April 14, 1910, was in cooperation with the Baltimore & Ohio Railroad Co. The second, third, and fourth experiments were made in cooperation with the Pennsylvania Railroad Co. The second shipment was made on December 24, 1910; the third, March 2, 1911; and the fourth, May 11, 1911.

Total amount of corn contained in each experiment, the average moisture content of the corn at the beginning of the experiment, and the average temperature of the corn immediately after loading and just prior to unloading

| Experiment No. | Period covered by experiment | In transit from Baltimore to Chicago and return | Held on track in Baltimore yards | Moisture content | Net corn in cars after loading | Shrinkage or loss in weight | | Average temperature of corn when - | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Loaded | Unloaded |
| | | | | Pct. | Lb. | Lb. | Pct. | °F. | °F. |
| 1 | Apr. 14 to May 11, 1910. | 5 cars | .... | 18.1 | 334,270 | 3,360 | 1.01 | 55.0 | 85.2 |
| 2 | Dec. 24,1910 to Jan. 20, 1911. | 4 cars | .... | 17.9 | 258,350 | 460 | .18 | 31.5 | 30.0 |
| | .... | .... | 4 cars | 17.9 | 258,200 | 520 | .20 | 31.5 | 33.9 |
| 3 | Mar. 2 to Mar. 29, 1911. | 4 cars | .... | 18.3 | 257,320 | 780 | .30 | 40.2 | 58.9 |
| | .... | .... | 4 cars | 18.3 | 256,540 | 775 | .30 | 40.0 | 58.3 |
| 4 | May 11 to June 1-3, 1911. | 4 cars | .... | 16.7 | 261,710 | 1,320 | .50 | 60.7 | 90.6 |
| | .... | .... | 4 cars | 16.7 | 257,350 | 1,870 | .73 | 61.6 | 99.6 |

### Conclusions

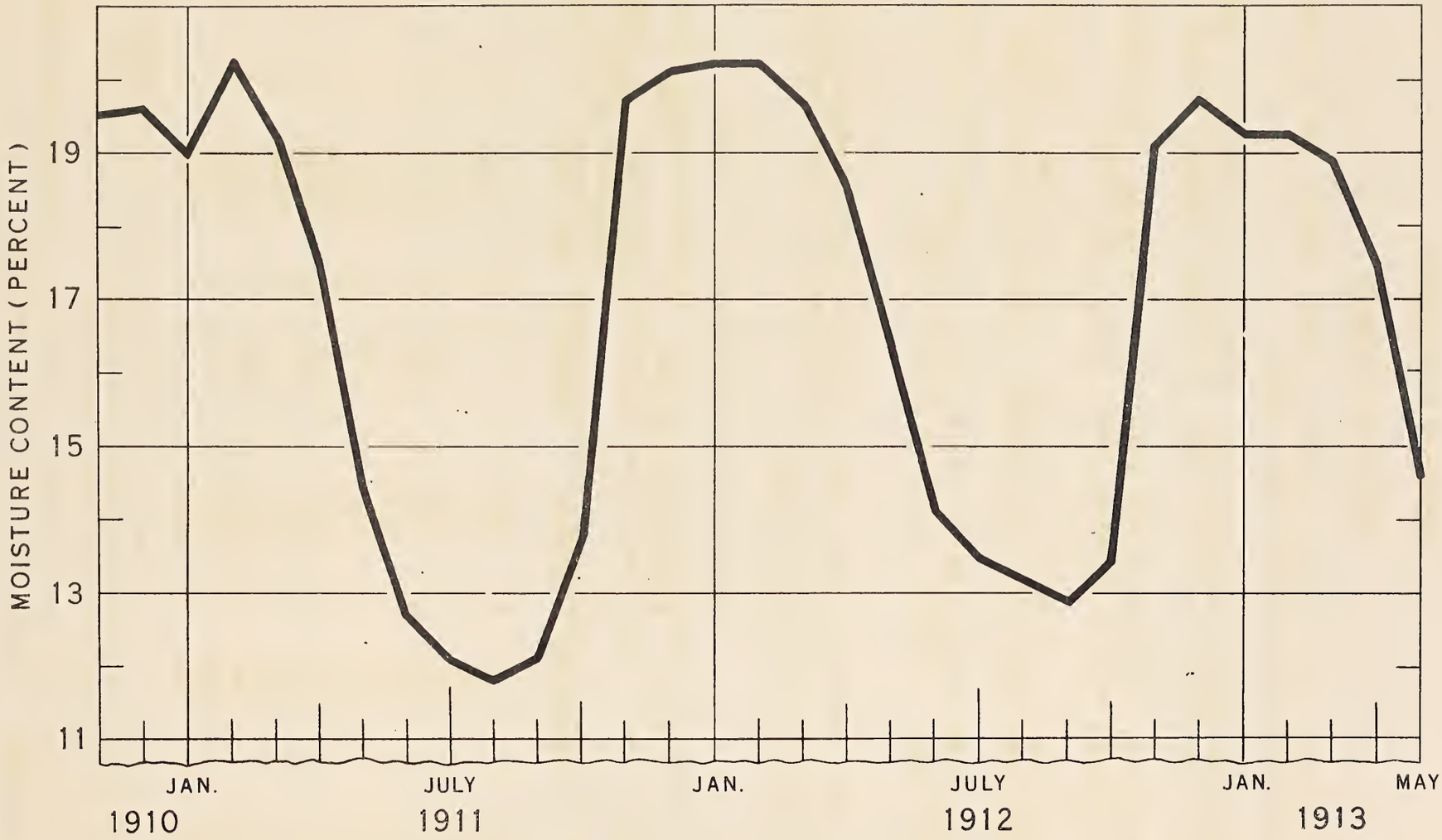
(1) There is a natural shrinkage in weight in commercial corn during transit and while in storage.

(2) Natural shrinkage in weight in corn that has become sour and hot is very rapid and may amount to several percents within a few days.

(3) Natural shrinkage varies with the moisture content of the corn and the atmospheric conditions to which it is exposed.

MOISTURE CONTENT OF SHELLED CORN BY MONTHS

The following chart was compiled from data obtained by the U. S. Department of Agriculture.




The average percentage of moisture in corn based on receipts at Baltimore, Chicago, and New Orleans, during the period November 1910 to May 1913. The chart shows plainly that corn dries out during the spring and summer months.

## SHRINKAGE OF EAR CORN

### Ear Corn in Cribs

Bowman, M. L., and Crossley, B. W. Corn. 479pp. Des Moines, Kenyon Printing and Mfg. Co., 1908.

Burlison, W. L., and Allyn, O. M. Prices and shrinkage of farm grains. Ill. Agr. Expt. Sta. Bull. 183, pp. 11-26. Urbana, November 1915.

Holden, P. G. Selecting and preparing seed corn. Iowa Agr. Expt. Sta. Bull. 77, pp. 167-230, rev. Ames, April 1904.

Ten Eyck, A. M., and Shoesmith, V. M. Indian corn. Kans. Agr. Expt. Sta. Bull. 147, pp. 225-295. Manhattan, June 1907.

Welton, F. A. Shrinkage in grain. Ohio Agr. Expt. Sta. Monthly Bull. 26, pp. 39-43. Wooster, February 1918.

The following table gives in tabular form a summary of the shrinkage that took place in ear-corn-shrinkage tests described in the five publications listed above.

Percentage of shrinkage, by months

| Month | Iowa 8-yr. av. | Illinois 9-yr. av. | Kansas 3-yr. av. | Ohio 5-yr. av. Damp corn 1/ | Ohio 8-yr. av. Well matured corn 2/ |
|---|---|---|---|---|---|
| | Percent | Percent | Percent | Percent | Percent |
| Nov. | 5.2 | 1.33 | - - - - | - - - - | - - - - |
| Dec. | 6.9 | 3.26 | - - - - | 4.75 | 5.28 |
| Jan. | 7.5 | 4.16 | - - - - | 7.90 | 7.03 |
| Feb. | 7.8 | 5.48 | 3.26 | 10.30 | 8.11 |
| Mar. | 9.7 | 6.95 | - - - - | 12.45 | 9.42 |
| Apr. | 12.8 | 9.99 | 5.16 | 18.20 | 11.62 |
| May | 14.7 | 13.10 | - - - - | 23.55 | 16.00 |
| June | 16.3 | 15.29 | 6.80 | 27.45 | 19.03 |
| July | 17.8 | 16.15 | - - - - | 28.85 | 20.03 |
| Aug. | 17.8 | 16.61 | 7.44 | 29.20 | 20.41 |
| Sept. | 18.2 | 16.39 | - - - - | 28.65 | 20.37 |
| Oct. | 18.2 | 16.54 | - - - - | 28.15 | 19.18 |

1/ The 5-year average moisture content Nov. 1, of the shelled corn was 30.29 percent; the cobs 50.21 percent.

2/ The 8-year average moisture content Nov. 1, immediately after shelling was 24.91 percent; the cobs 41.51 percent.

Holden, P. G. Selecting and preparing seed corn. Iowa Agr. Expt. Sta. Bull. 77, pp. 167-230, rev. Ames, April 1904.

A series of experiments was conducted at the Iowa Agricultural Experiment Station for 8 consecutive crop years to test the shrinkage of ear corn in cribs. Different types of corn, representing average conditions, were used and about 100 bushels on the ear were placed in a crib built upon scales and careful weighings were made weekly.

Summary of the experiments is as follows:

Shrinkage of corn by years and months

| Month | 1898-9 | 1899-0 | 1900-1 | 1902-3 | 1903-4 | 1904-5 | 1905-6 1/ | 1906-7 1/ | Av. | Mo. rate |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. |
| Nov. | 8.1 | 4.0 | 2.6 | 1.8 | 8.2 | 8.3 | 7.2 | 1.4 | 5.2 | 5.2 |
| Dec. | 8.9 | 2.6 | 3.6 | 3.6 | 10.5 | 9.5 | 9.2 | | 6.9 | 1.7 |
| Jan. | 9.0 | 2.3 | 4.6 | 5.7 | 11.7 | 10.2 | 9.0 | | 7.5 | .6 |
| Feb. | 10.1 | 2.7 | 5.9 | 6.0 | 12.6 | 10.5 | 11.6 | 3.1 | 7.8 | .3 |
| Mar. | 10.5 | 4.4 | 6.8 | 9.2 | 14.9 | 15.3 | 12.0 | 4.5 | 9.7 | 1.9 |
| Apr. | 14.6 | 6.6 | 8.6 | 15.3 | 19.3 | 15.4 | 15.1 | 7.1 | 12.8 | 3.1 |
| May | 15.0 | 7.4 | 11.4 | 15.1 | 24.3 | 19.0 | 17.5 | 8.2 | 14.7 | 1.9 |
| June | 16.0 | 8.0 | 12.4 | 21.4 | 26.0 | 19.8 | 19.1 | 7.6 | 16.3 | 1.6 |
| July | 17.7 | 7.4 | 15.9 | 22.5 | 26.7 | 20.2 | 19.5 | 8.2 | 17.8 | 1.0 |
| Aug. | 18.0 | 7.1 | 15.0 | 22.6 | 29.5 | 21.2 | 18.7 | 8.6 | 17.8 | 1.5 |
| Sept. | 19.9 | 7.6 | 14.0 | 24.8 | 30.5 | 20.6 | 19.3 | 8.9 | 18.2 | .4 |
| Oct. | 19.7 | 7.9 | 13.6 | 24.9 | 30.0 | 20.8 | 19.3 | 9.5 | 18.2 | .0 |

1/ 1905-6 and 1906-7 shrinkage tests in Bowman and Crossley, "Corn" p. 208.

## Shrinkage Depends on Condition of Ear Corn when Stored

Smith, C. D. Shrinkage of farm products. Mich. Agr. Expt. Sta. Bull. 191, pp. 159-172. Agricultural College, May 1901.

Experiments conducted by the Michigan Agricultural Experiment Station show that the loss in weight of ear corn depends upon the condition of the ears when hauled to the crib.

Very damp corn cribbed early in October shrank in weight 30 percent by the middle of February, while dry corn cribed October 21 had shrunk by the last of January, 11 percent. In another case corn very dry when hauled, shrank by the first of January less than 3 percent.

The relation between the weight of cobs and kernels does not stay constant as the ears dry. When first husked fully 25 percent of the weight of the ear is in the cob. Elaborate experiments at the Houghton farm showed that the shelled corn lost in weight about 7.45 percent from October to March, while the cob lost fully 36 percent. The ears shrank on the average during the winter 15.28 percent.

## SHRINKAGE OF COBS VS. KERNELS

### Ear Corn Stored in Country Cribs

The U. S. Department of Agriculture carried on a series of experiments during 1910 and 1911, to determine the relation between the drying out of the corn kernels and the corn cobs. The following table represents the results of tests made on corn stored in several country cribs in Illinois.

The moisture content in the kernels and cobs varies with each crop and also with varieties, the average for the crop depending somewhat upon the weather conditions.

It will be noted that immediately after harvesting the cobs averaged much higher in moisture than the kernels, but dried out much faster in storage, and contained less moisture than the kernels during the following summer months.

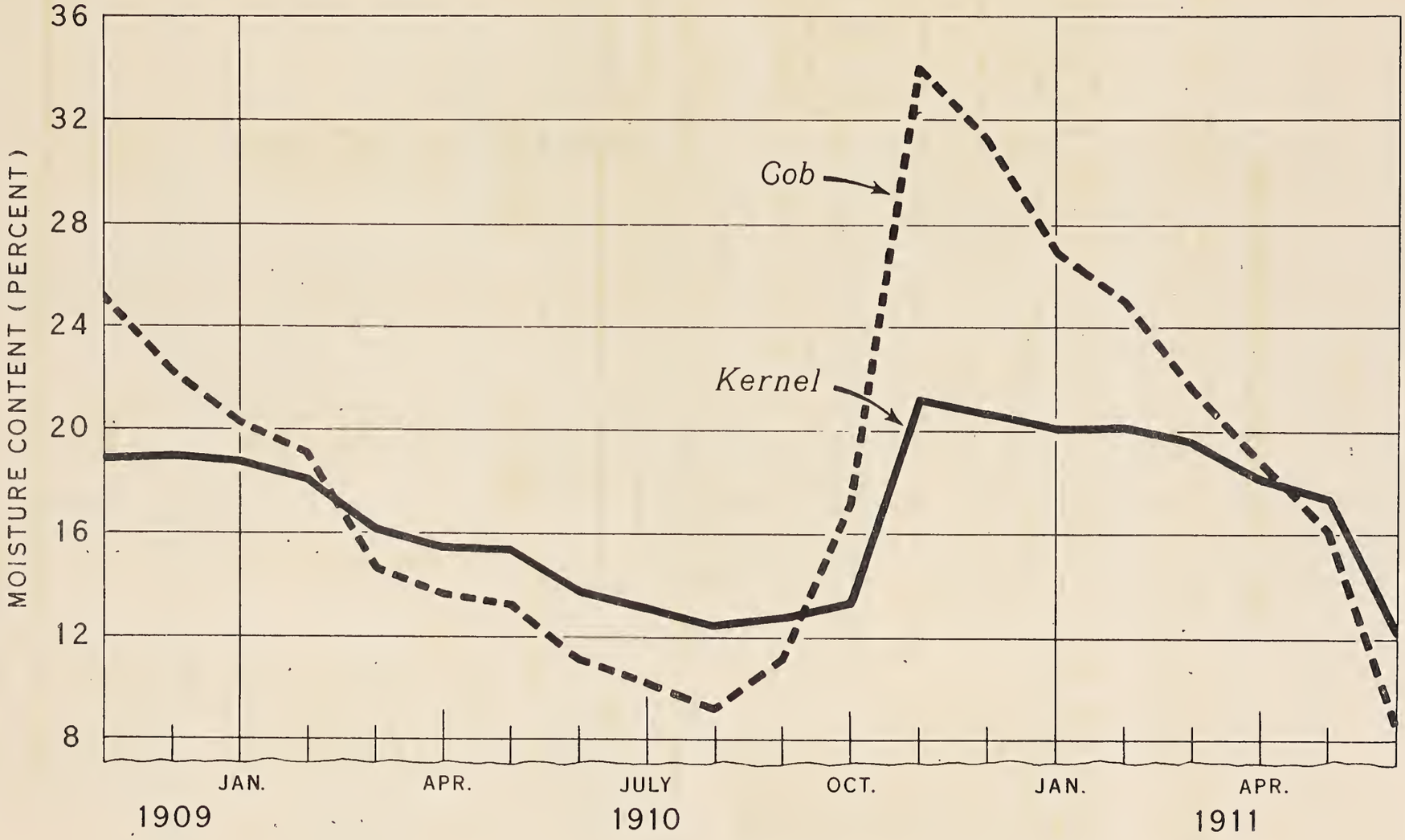
Moisture in the cobs and kernels of corn stored in several country cribs in Illinois

| Year | Month | Average moisture content of - Cobs | Kernels |
|---|---|---|---|
| | | Percent | Percent |
| 1910 | November | 33.8 | 21.7 |
| | December | 31.2 | 20.6 |
| 1911 | January | 27.0 | 20.2 |
| | February | 25.1 | 20.3 |
| | March | 21.7 | 19.6 |
| | April | 19.0 | 18.5 |
| | May | 16.3 | 17.4 |
| | June | 8.8 | 12.2 |
| | July | . . . | . . . |
| | August | . . . | . . . |
| | September | . . . | . . . |
| | October | 8.7 | 11.7 |
| | November | 29.1 | 20.9 |
| | December | 22.9 | 19.8 |

The results for the two crops years (1909-10 and 1910-11) are graphically shown in the following chart:

## SHRINKAGE OF COBS VS. KERNELS

**Ear corn stored in country cribs in Illinois, sampled and tested by the U. S. Department of Agriculture.**




**Average moisture content of the cobs and kernels of the ear corn during different seasons of the year.**

## Ear Corn Stored in Unheated Barn

Bailey, C. H. Respiration of shelled corn. Minn. Agr. Expt. Sta. Tech. Bull. 3, 44pp. St. Paul, September 1921.

p. 12. "A lot of Johnson County white dent corn, grown at the Maryland Agricultural Experiment Station in 1920, was employed in an experiment to determine the comparative rate of change in moisture content of cob and kernels while curing. This corn was cut and shocked about October 21, 1920, and the ears were removed from the stalks and husked on October 28. One portion of this husked corn was ... stored in an unheated barn. Moisture content of the cob and kernels ... on different dates is shown in the following table. ... These data show that as the ear dries out, the cob, which has a materially higher initial moisture content than the kernels, loses moisture at a more rapid rate; in this experiment containing less moisture than the kernels when the latter had a moisture content below 14 percent."

Moisture in cobs and kernels of ear corn at different times during curing process

| Date | Moisture content | |
|---|---|---|
| | Cured in unheated barn - | |
| | Cobs | Kernels |
| | Percent | Percent |
| 1920 | | |
| Oct. 28 1/ | 42.02 | 25.77 |
| Nov. 4 | . . . | . . . |
| Nov. 12 | 32.07 | 20.69 |
| Nov. 24 | 26.31 | 18.37 |
| Nov. 29 | . . . | . . . |
| Dec. 3 | 24.90 | 17.90 |
| Dec. 24 | 22.79 | 17.21 |
| 1921 | | |
| Jan. 15 | 20.49 | 16.54 |
| Feb. 16 | 16.41 | 15.20 |
| Mar. 18 | 10.04 | 13.96 |

1/ Date husked.

## CHANGE IN WEIGHT OF WHEAT

### Shrinkage of Wheat in Storage

Burlison, W. L., and Allyn, O. M. Prices and shrinkage of farm grains. Ill. Agr. Expt. Sta. Bull. 183, pp. 11-28. Urbana, November 1915.

This bulletin reports the results of experiments made at two stations on the shrinkage of wheat.

Condition and percentage of shrinkage of wheat stored in two States for given periods

| Station | Length of storage | Condition of tests | Percentage shrinkage |
|---|---|---|---|
| Ohio | 3 years | 14 samples, thoroughly dry, stored in bin of wheat for nearly 1 year; then left in corner of bin until expiration of 3 years. | 0 to 4.94<br>Av. 2.32 |
| Michigan | 332 days | Wheat dry and in good condition. Bins open at top. Soft White ..... | .5 |
| | | Hard Red ..... | .1 |
| Michigan | 10 days | 1,500 bushels stored in elevator in hard and dry condition after threshing. (Christian Breisch & Co., Millers, North Lansing, Michigan.) | 2.0 |

It was found that wheat shrank comparatively little after it had gone through the sweat. The estimate is made that the shrinkage will be from 1 to 2 percent in 6 months when stored in large elevators.

Welton, F. A. Shrinkage in grain. Ohio Agr. Expt. Sta. Monthly Bull. 26, pp. 39-43. Wooster, February 1918.

A test was conducted by the Ohio Agricultural Experiment Station to determine the shrinkage of wheat in storage. Forty bushels (2,400 pounds) were stored in a bin in a granary each year for 5 years. The wheat used usually stood in the shock several weeks before threshing. The results of this test are shown in the following tables.

The 5-year average moisture content of the wheat at the beginning of each month

| Date | Moisture content | Date | Moisture content |
|---|---|---|---|
| | Percent | | Percent |
| Sept. 1 | 13.53 | Mar. 1 | 13.85 |
| Oct. 1 | 13.39 | Apr. 1 | 13.95 |
| Nov. 1 | 13.65 | May 1 | 13.49 |
| Dec. 1 | 14.02 | June 1 | 13.75 |
| Jan. 1 | 13.79 | July 1 | 13.23 |
| Feb. 1 | 13.34 | Aug. 1 | 13.34 |

Change in weight of wheat during storage

| Date of experiment | | Quantity weighed - | | Gain (+) or loss (-) | |
|---|---|---|---|---|---|
| Beginning | Ending | In | Out | | |
| | | Pounds | Pounds | Pounds | Percent |
| Aug. 24, 1911 | Oct. 23, 1912 | 2,400 | 2,395 | - 5 | - 0.21 |
| Sept. 3, 1912 | Aug. 7, 1913 | 2,400 | 2,383 | - 17 | - .71 |
| Aug. 8, 1913 | Aug. 10, 1914 | 2,400 | 2,426 | + 26 | + 1.08 |
| Aug. 10, 1914 | Aug. 23, 1915 | 2,400 | 2,395 | - 5 | - .21 |
| Sept. 6, 1915 | Sept. 2, 1916 | 2,400 | 2,352 | - 48 | - 2.00 |
| Average annual loss ..... | | | | - 9.8 | - .41 |

## Change in Moisture Content of Pacific Northwest Wheat

Baldwin, R. L. Rept. from U. S. Dept. Agr. Fed. Grain Supervision Proj. Letter. Washington, D. C., Feb. 18, 1921.

The report is based on samples secured from 2,034 cars of wheat, received at Portland, Oreg., during the years 1914-16. The report shows that the wheat of the Pacific Northwest is very dry at time of threshing and before the so-called rainy season, and that from then on it gradually takes on moisture from the atmosphere until about March, from which time until August some of the moisture is given off.

The average moisture content of the wheat for the 3 years was 9.1 percent in August, and 11.3 percent in March, an increase of 2.2 percent. In July the average was 10.6 percent, or 1.5 percent higher than for August. Some years and some sections are of course more dry than others, but the data for each separate year and section show the same relative changes.

Car receipts of Pacific Northwest wheat at Portland, Oreg. The following table gives a summary of the moisture content by months of wheat of all varieties from all sections of the Pacific Northwest for the 3 years 1914-16.

Summary of moisture content of all varieties of Pacific Northwest car receipts of wheat for 1914-16 at Portland, Oreg.

| Month | Total number of samples | Moisture content, percentage | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 7.0 and under | 7.1 to 8.0 | 8.1 to 9.0 | 9.1 to 10.0 | 10.1 to 11.0 | 11.1 to 12.0 | 12.1 to 13.0 | 13.1 to 14.0 | 14.1 to 15.0 | 15.1 to 16.0 | 16.1 and over | Av. | Max. | Min. |
| | | Number of cars | | | | | | | | | | | Pct. | Pct. | Pct. |
| Aug. | 179 | 7 | 47 | 58 | 29 | 16 | 7 | 4 | 5 | 2 | 2 | 2 | 9.1 | 19.9 | 6.6 |
| Sept. | 145 | | 19 | 62 | 41 | 12 | 8 | 3 | | | | | 9.1 | 12.4 | 7.3 |
| Oct. | 239 | | 12 | 68 | 94 | 39 | 13 | 11 | 1 | 1 | | | 9.6 | 14.2 | 7.3 |
| Nov. | 227 | | 5 | 32 | 82 | 55 | 21 | 17 | 11 | 1 | 1 | 2 | 10.3 | 17.1 | 7.2 |
| Dec. | 190 | | 3 | 18 | 56 | 56 | 27 | 20 | 5 | 4 | 1 | | 10.6 | 15.9 | 8.0 |
| Jan. | 155 | 1 | | 8 | 33 | 50 | 34 | 18 | 8 | 2 | | 1 | 10.9 | 17.9 | 6.8 |
| Feb. | 165 | | 2 | 3 | 31 | 54 | 40 | 21 | 7 | 6 | | 1 | 11.1 | 16.8 | 7.4 |
| Mar. | 195 | | | 5 | 26 | 46 | 78 | 27 | 11 | 2 | | | 11.3 | 14.6 | 8.4 |
| Apr. | 200 | | | | 21 | 57 | 82 | 30 | 8 | 2 | | | 11.2 | 14.2 | 9.3 |
| May | 214 | | | | 23 | 60 | 93 | 31 | 2 | | | | 11.2 | 13.3 | 9.0 |
| June | 109 | | 1 | 1 | 14 | 39 | 37 | 11 | 6 | | | | 11.1 | 14.0 | 7.9 |
| July | 16 | | 1 | 1 | 2 | 7 | 4 | 1 | | | | | 10.6 | 12.8 | 7.6 |
| All mos. | 2,034 | 8 | 90 | 256 | 452 | 496 | 444 | 194 | 64 | 20 | 4 | 6 | 10.5 | 19.9 | 6.6 |

## CAPACITY OF WHEAT AND MILL PRODUCTS FOR WATER

Stockham, W. L. The capacity of wheat and mill products for water. N. Dak. Agr. Expt. Sta. Bull. 120, pp. 97-131. Agricultural College, January 1917.

p. 98. "One of the well-known relationships of the moisture content of wheat is its approximate parallelism to the humidity of the atmosphere. The normal moisture content of wheat stored in a dry region like Utah being much lower than in other sections where the humidity of the atmosphere is greater. In the same locality it varies with the time of year due to the same cause. That its products vary similarly has been shown by numerous storage experiments including many at this station.

"Balland placed wheat and flour in a vessel containing water but not in contact with it and thus increased the moisture from 15.4 percent to 18 percent for the wheat without reaching the maximum; and to 21 percent for the flour. The absorption was much more rapid at the beginning of the test.

"The moisture problem would be relatively simple if all samples responded the same under like conditions, but unfortunately they do not, as they differ in their rate of change, or natural capacity. Whatever

differences of this kind exist, must have a basis within the wheat or its products and in a general way may be regarded either as chemical or physical."

p. 107. "The amount of water which wheat or a mill product will contain at any given time may not depend so much upon the existing atmospheric conditions as upon the length of time those conditions have prevailed. If the bulk of wheat is great the rate of change will be correspondingly slower and dependent on the rate of gas exchange. If the bulk of it is very great, only the surface layer will be at all affected by atmospheric changes unless air should be forced through by artificial means. Wheat in the shock, stack, small exposed bins, or being handled, may respond to its surroundings."

p. 129. "The capacity of wheat and its products for atmospheric moisture and water increases as the physical equilibrium between the component particles is approached.

"Wheat has a higher moisture capacity than any of its products. The natural capacity for water vapor of wheat and its products under the same conditions is as follows: wheat 12.4 percent, patent flour 11.31 percent, bran 11.17, first clear flour 11.07, second clear flour 10.86, and shorts 10.5 percent. This is in the reverse order of their protein contents (the wheat excepted).

"The capacity of wheat for atmospheric moisture is greater at zero than at higher temperatures, diminishing with increase in temperature. Above 60° C. it is dependent upon chemical changes which in turn are dependent upon the amount of moisture available. With the humidity zero the capacity is zero regardless of the temperature. At the saturation point between zero and 40° C. the theoretical limits are only one-third to one-half reached because of secondary changes produced by enzymes, bacteria and molds.

"Previously sprouted wheat absorbs both water and water vapor more rapidly than wheat in the natural state. It reaches its maximum sooner but does not reach as high a maximum as the normal wheat.

| | Maximum moisture content - | |
|---|---|---|
| | Sprouted | Natural |
| | Percent | Percent |
| Saturated atmosphere ..... | 35.42 | 37.43 |
| Immersed in water ..... | 68.9 | 101.8 |

"Wheat products have a more rapid rate of adjustment to modified moisture conditions than wheat and are more subject to secondary changes.

"Germination does not take place from water absorbed from the atmosphere (condensation excluded).

"The rate of change of the moisture content of wheat in the atmosphere or in water becomes slower as the maximum limits are approached.

"In water (when growth does not take place) the capacity of wheat is greatest at zero, decreasing with increase in temperature until at approximately 60° C. hydrolysis begins. The rate of absorption is many times more rapid with the higher temperatures. Before secondary changes have advanced noticeably a ten degree rise in temperature almost doubles the rate of absorption.

"Secondary changes are nearly eliminated at zero. The losses are least at that temperature, amounting to only 5.5 percent in 27 days. At 25° C. they amount to 23.4 percent in 5 days.

"The absorptive capacity of the wheat varies inversely as the water absorbing power of the flour produced from the same wheat, and as a rule inversely to the protein content.

"The Durums are similar to hard red spring wheat samples of the same protein content in rate and quantity of water absorbed.

"Pressure upon a water wheat mixture where either may change in volume at the expense of the other does not appreciable affect the rate or amount of water absorbed by wheat where the secondary changes are eliminated or are slight.

"Pressure upon the wheat itself diminishes markedly its capacity and rate of absorbing water."

## CHANGES DURING STORAGE IN THE MOISTURE CONTENT OF WHEAT AND OATS RAISED UNDER IRRIGATION AND DRY-FARMING CONDITIONS

Harris, F. S., and Thomas, George. The change in weight of grain in arid regions during storage. Utah Agr. Expt. Sta. Bull. 130, pp. 303-313. Logan, January 1914.

Experiments were conducted by the Utah Agricultural Experiment Station to determine the gain or loss in weight of wheat and oats raised under irrigation and dry-farming conditions and harvested and thrashed by the methods usually employed in arid regions. The grain was taken directly from the thrashing machine and placed in burlap bags. The bags of grain were placed on a platform where there could be a free circulation of air, in a grain room of the barn belonging to the Agricultural College at Logan, Utah. The experiment was begun August 17, 1911 and the grain kept in storage for 2 years.

A determination of the amount of moisture at the beginning and at the end of the experiment was made with the following result:

Moisture in grain at beginning of experiment and at the end, 2 years later

| Lot No. | Grain | Moisture content August 1911 | Moisture content August 1913 | Gain |
|---|---|---|---|---|
| | | Percent | Percent | Percent |
| 1 | Wheat | 6.51 | 9.25 | 2.74 |
| 2 | Wheat | 6.48 | 9.23 | 2.75 |
| 3 | Wheat | 6.98 | 9.30 | 2.32 |
| 4 | Wheat | 7.33 | 9.31 | 1.98 |
| 7 | Wheat 1/ | 8.67 | 9.28 | .61 |
| 8 | Wheat 1/ | 7.54 | 8.99 | 1.45 |
| 9 | Wheat | 6.72 | 8.95 | 2.23 |
| 5 | Oats 1/ | 6.25 | 8.57 | 2.32 |
| 6 | Oats 1/ | 6.12 | 8.24 | 2.12 |

1/ Raised under irrigation. All others raised under dry farming.

The results of the experiments show:

1. In all nine cases there was a gain in moisture and consequently in weight which was gradual during the fall and winter until a total gain of from 3 to nearly 5 percent had been made.

2. During the spring and summer and into the fall there was a loss in moisture content and consequently in weight, but the grain always weighed more than at thrashing time. The grain increased again during the winter, and during the second winter the grain became even heavier than during the first. This is illustrated in the accompanying chart.

3. There seemed to be little difference in the change in moisture content in the grain raised under irrigation or under dry-farming conditions.

4. The method of harvesting, that is, whether it was done with a combine harvester and thrashed at once, with the header and stacked 10 days before threshing, or cut, bound, and left standing in the shock 10 days before thrashing, seemed to have little effect on the change in weight.

5. It is probable that the stage of maturity and dryness at harvest are the chief factors that determine changes in weight during the first fall and winter after harvesting.

6. The changes in weight are due to the absorption of moisture from the atmosphere during the fall and winter months and to the giving off of moisture during the spring and summer months.

The changes in the weight resulting from the absorption of moisture, or drying out of the grain from month to month, during the period from August 1911 to August 1913, for three of the lots, are illustrated in the chart on page 17. Similar changes took place in the remaining lots.

MOISTURE CONTENT OF WHEAT AND OATS BY MONTHS


Gain and loss in weight due to natural absorption or drying out of moisture in wheat and oats, harvested and stored in Utah.

## CHANGE IN WEIGHT OF OATS IN STORAGE

### Moisture Absorption of Oats Stored in Granary

Welton, F. A. Shrinkage in grain. Ohio Agr. Expt. Sta. Monthly Bull. 26, pp. 39-43. Wooster, February 1918.

An experiment was conducted by the Ohio Agricultural Experiment Station to determine the amount of shrinkage in oats, while in storage. Forty bushels (1,280 pounds) were stored in a small bin in a granary for approximately 1 year, after which the contents of the bin were reweighed. An experiment of this kind was conducted through 5 consecutive years. The grain used in this test was threshed in some instances directly from the field and in some from the mow, but in all cases it was considered in good condition for storage. Results of this experiment are given in the following tables.

The 5-year average moisture content of the oats at the beginning of each month

| Date | Moisture content | Date | Moisture content |
|---|---|---|---|
| | Percent | | Percent |
| Sept. 1 | 12.84 | Mar. 1 | 12.97 |
| Oct. 1 | 13.02 | Apr. 1 | 12.95 |
| Nov. 1 | 12.54 | May 1 | 13.04 |
| Dec. 1 | 13.19 | June 1 | 13.17 |
| Jan. 1 | 13.45 | July 1 | 13.03 |
| Feb. 1 | 12.77 | Aug. 1 | 12.67 |

Change in weight of the oats in storage

| Date of experiment - Beginning | Date of experiment - Ending | Quantity weighed - In | Quantity weighed - Out | Gain (+) or loss (-) | |
|---|---|---|---|---|---|
| | | Pounds | Pounds | Pounds | Percent |
| Aug. 24, 1911 | Oct. 23, 1912 | 1,280 | 1,287 | + 7 | + 0.55 |
| Sept. 3, 1912 | Aug. 7, 1913 | 1,280 | 1,270 | - 10 | - .78 |
| Aug. 8, 1913 | Aug. 19, 1914 | 1,280 | 1,258 | - 22 | - 1.72 |
| Aug. 10, 1914 | Aug. 25, 1915 | 1,280 | 1,342 | + 62 | + 4.84 |
| Sept. 6, 1915 | Sept. 2, 1916 | 1,280 | 1,254 | - 26 | - 2.03 |
| Average annual gain | | | | + 2.2 | + 0.17 |

## Shrinkage of Oats

Burlison, W. L., and Allyn, O. M. Prices and shrinkage of farm grains. Ill. Agr. Expt. Sta. Bull. 183, pp. 11-26. Urbana, November 1915. (Compiled from Mich. Expt. Sta. Bull. 191, Shrinkage of farm products, by C. D. Smith. 1901.)

Results of experiments on the shrinkage of oats

| Station | Length of storage | Condition of tests | Shrinkage |
|---|---|---|---|
| | | | Percent |
| Ohio | Sept. 1892 to Mar. 1893 (about 6 mos.) | 54 varieties aggregating 4,243 lbs., recleaned, hung in ordinary bags, in artificially warmed rooms ..... | 1.00 |
| Michigan | Aug. 11, 1896 to Mar. 18, 1897 (7 mos. 7 days) | 100 bushels binned, without re-cleaning, 1 hour after threshing. Dry conditions, but wet once with rain while in shock..... | .21 |
| Michigan | Sept. 13, 1897 to Mar. 1, 1898 (5 mos. 17 days) | Stored in sheep barn | |
| | | 806 lbs. International oats ..... | 1.61 |
| | | 550 lbs. New Marine oats ..... | 2.00 |
| Michigan | Oct. 8, 1899 to May 10, 1900 (7 mos. 2 days) | 1,038 lbs. stored in tight bin in Experiment Station barn ..... | 3.40 |

## METHOD OF OBTAINING LOSS IN WEIGHT OF GRAIN BASED ON ITS REDUCTION IN MOISTURE CONTENT

Duvel, J. W. T. Moisture content and shrinkage in grain. U. S. Dept. Agr., Bur. Plant Indus. Circ. 32, 13pp. Washington, D. C., July 6, 1909.

The method for finding the final weight and shrinkage on any given lot of grain is described in the above-mentioned bulletin. Where the original weight of the grain before drying and its moisture content before and after drying are known, the final weight is found by multiplying the original weight of the grain by the percentage of dry matter before drying and dividing by the percentage of dry matter after drying. The original weight less the final weight equals the shrinkage.

Stated in terms of proportion it would be:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Percentage of dry matter after drying | : | Percentage of dry matter before drying | :: | Original weight | : | Final weight |

## COMPARATIVE VALUES ON A DRY-MATTER BASIS

Boerner, E. G. The intrinsic values of grain, cottonseed, flour, and similar products, based on the dry-matter content. U. S. Dept. Agr. Bull. 374, 32pp. Washington, D. C., Oct. 17, 1916.

p. 2. "Other things being equal, different lots of grain, cottonseed, flour, meal, etc., have an intrinsic value to the consumer, - such as the livestock feeder, the manufacturers of corn products, the cottonseed crusher, the miller of wheat, and the baker - in proportion to the amount of dry matter contained in each lot. The grain, cottonseed, and flour which contain the least moisture of course contain the greatest amount of dry matter and not only has the highest intrinsic value on account of this high dry-matter content, but it is also of greater value because of its better keeping qualities while in storage."

The intrinsic values of the dry matter in a unit of grain having different moisture contents are given in a series of tables in this bulletin.

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